



METHODOLOGY FOR ADDRESSING D&D MEASUREMENT CHALLENGES

Dismantling a nuclear installation is often difficult due to the lack of knowledge about the position, identification and radiological characteristics of the contamination. The contamination is particularly difficult to define in a significant global background when the activities are relatively high. For example, identification and estimation of the activity becomes more complex in hot cells, where space is limited and human intervention is costly in terms of accumulated dose.

When embarking on a dismantling project, a number of elements must be specified as they relate to nuclear measurements:

- Definition of the needed investigations
- Detector choice
- Dose rate modeling
- Coupling dose rate measurement and model
- Coupling gamma spectrometry measurement model
- Coupling neutron measurement and model

These challenges often require application of nuclear measurement expertise in unique ways in order to accomplish the goals of the program. With careful methodology, it is possible to achieve not only measurement results, but also activities, and localization. Eventually it is possible to guaranty safety or process threshold corresponding to the needs of the site.

While the general methodology may be appropriate for similar dismantling efforts, in this example, we review the challenges of dismantling the facilities of a reprocessing plant: from dissolution to U, Pu and fission products (FP) extraction and storage in tanks. In such scenarios, a transversal project team may be assembled to support all dismantling sub-projects. Typically, the project team is charged with:

1. Definition of dismantling scenario
2. Design of waste packaging installation
3. Good waste categorization
4. Radioactive discharges optimization
5. Safety analysis (dose rate, criticality...)

The investigation may require many skills and means including:

- Video investigation capabilities
- Documentary research
- Laboratory analysis
- Nuclear measurements and modeling

This particular discussion will focus on nuclear measurements and modeling as they relate to the dismantling effort.

NUCLEAR INVESTIGATIONS IN A DISMANTLING PROJECT

Necessary Data Retrieval

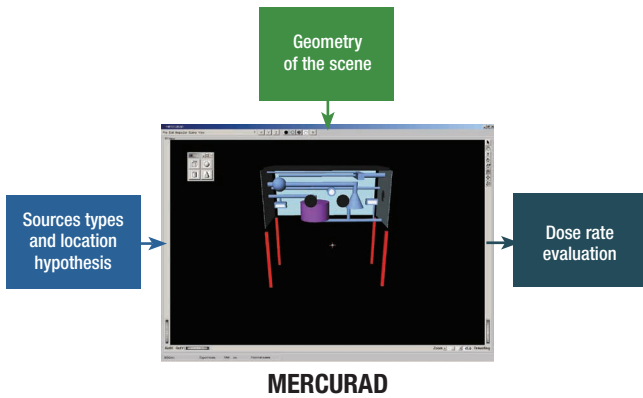
The first phase of nuclear measurement investigation is crucial. A facility preparing to be dismantled usually has a long history of operations with numerous events which have occurred during its lifetime. The knowledge of these events is very important in the definition of measurement strategy. These first assumptions usually come from interviews with the previous operators of the facility, allowing definition of a first model. A good expectation in an activity evaluation is already taken into account with the right information (detector choice for example).

Scene Modeling

For a high-activity cell, a first model evaluation can save a lot of money during the investigation phase. From large activities panel assumptions and geometry descriptions of the scene, sources would be able to be placed in the model and dose rate evaluation would be determined as a range of magnitude. This information will define the type of investigation:

- Is the staff able to enter the cell?
- Possibility to introduce nuclear measurement?
- Logistics required for nuclear measurements?

The MERCURAD application may be used for gamma emitters. The application is based on MERCURE V6 (reference [1]) gamma attenuation code developed by the French Atomic Commission at Saclay (CEA/SERMA). This code is used but also sold by CANBERRA. It has a very convenient interface which can be used by a technician for modeling a complex scene within about 30 minutes. Figure 1 summarizes this first part of the methodology.



MERCURAD

Figure 1
MERCURAD dose rate evaluation code.

For neutron emitters, only MCNP is used because no simplified code for 3D geometries exists yet.

First Measurements to Confirm Hypothesis

The first evaluation of dose rate will allow the selection of detectors, electronics and associated shielding and/or collimators. For very complex problems (concerning mainly high activity cells), several iterations are needed. Simple measurements have to be done first, before complex measurement on model and refinement of the original hypothesis.

MEASUREMENT POSSIBILITIES

Main Solutions

The measurement solutions are numerous. Usually only gamma and neutron detectors are used. Alpha and beta emitters are detected by their gamma emission, which explains why the ratio between gamma and alpha has to be known in the case of total gamma counting (without spectrometry). This ratio can have a deep impact in waste categorization. Gamma spectrometry measurement will be preferred when this ratio cannot be easily identified or when the gamma emitters are numerous.

Total Counting Measurement

Gamma Measurement

Ionization chambers are usually chosen because of their sensitivity and their ability to be used in very hot cells. In that case, the electronics will be placed away from the detector and current amplification electronics will be preferred. Geiger Mueller dose meters can also be used. Such detectors can be very small and are very useful when there is little space to introduce the detector into the hot cell.

Neutron Measurement

Because of their sensitivity, ³He tubes are preferred. But they are also sensitive to gamma. In the case of high gamma emission, BF₃ detectors will be chosen. For very high neutron emission, fission chambers can also be used. All these detectors can only detect thermalized neutrons. If the neutron spectrum in the cell is not a thermal spectrum, the neutrons will have to be thermalized, usually with polyethylene blocks which increase the space needed around the detector.

Source Location: CARTOGAM Possible Use

Use of the CARTOGAM (gamma camera) is appropriate (see reference [2]) when the location is not known and when it is very important to know the location of the radioactivity in order to define the dismantling scenario. This tool can drastically decrease the number of needed measurements.

The main advantage of the CARTOGAM system compared to others is that it superimposes visible and gamma images using the same optics (see Figure 2).

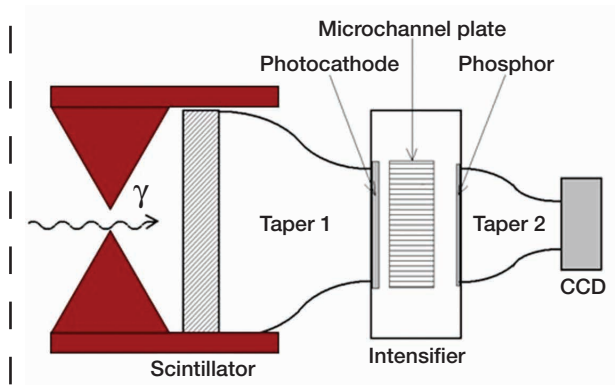


Figure 2
CARTOGAM measurement head with its PC and scheme of the image processing.

The use of CARTOGAM will also simplify the need for sampling. The localization of the needed sample is made easier as the sample contains radionuclides. Laboratory analysis on these samples will determine all radionuclides and specific ratios.

To avoid expensive laboratory analyses, gamma spectrometry measurements can also be done in the field.

Source Identification: Use of NaI, CZT, or Ge Detectors

While gamma spectrometers are useful for source identification, NaI detectors are a cheaper solution, with a poorer resolution (<10% at ¹³⁷Cs) but a good efficiency for very low activity determination. They will be preferred for simple gamma spectra with known radionuclides only the proportion of which has to be determined.



Figure 3
CARTOGAM coupled with a CZT detector.

CZT (Cd-Zn-Te) detectors (Figure 3) are small and will be preferred in high activity cells. Their resolution is better than NaI detectors (usually 1.5% to 3%). CANBERRA frequently uses this type of detector coupled with CARTOGAM or adapted to the InSpector™ 1000 Hand-Held MCA (Figure 4), which easily distinguishes ⁶⁰Co from ¹³⁷Cs.

The last and best solution is to use germanium detectors with a resolution usually around 0.2%. This is the solution for very complex spectra. This type of detector can determine the isotopic composition of U and Pu. CANBERRA developed BEGe (Broad Energy Germanium) approximately 15 years ago. Such a detector coupled with an ISOCS™ modeling code (see reference [4]) is a very versatile solution. CANBERRA also proposes a wide range of Ge detectors for specific problems.



Figure 5
Cart for Ge detector and associated collimator.

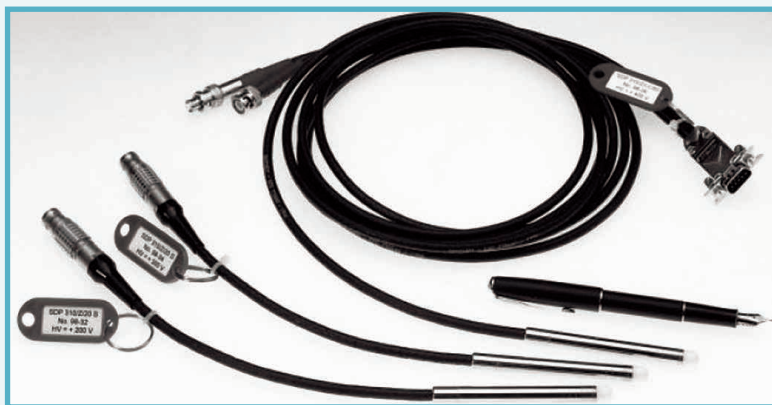


Figure 4
InSpector 1000 with NaI and CZT probes to be introduced into very small holes.

SCENE Modeling SOLUTIONS

Why Do We Model the Scene?

Detectors give counts per second. The modeling of the scene with source location assumptions, allows determining not only counts, but also proportions, radionuclides and activities.

The use of CARTOGAM before modeling can help to make better assumptions in source location and drastically decrease the uncertainties. The following figure illustrates this methodology.

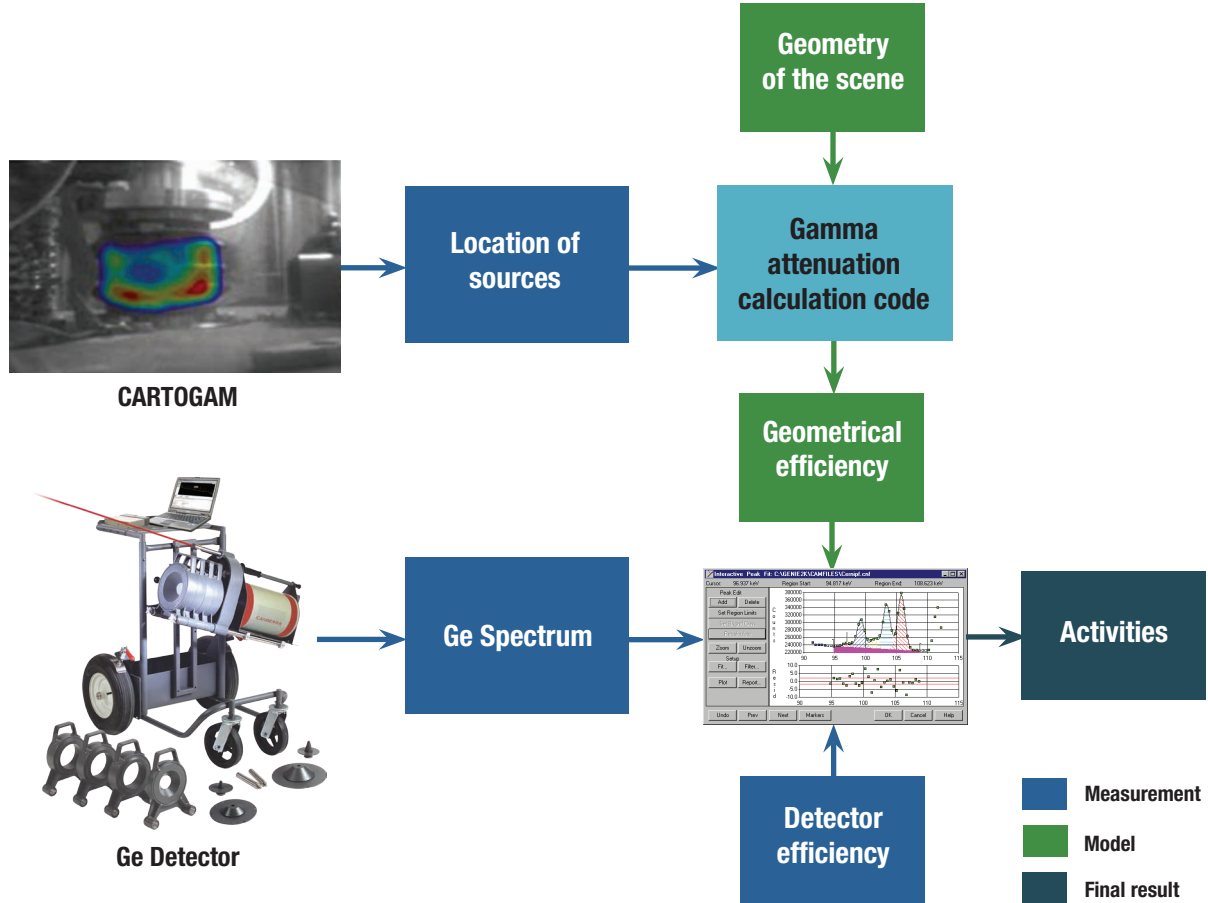


Figure 6
Methodology for activity determination.

The determination of geometrical efficiency and detector efficiency allow determination of activities from a spectrum in counts per second via the following formula:

$$A(\text{Bq}) = \frac{M(\text{cps})}{I \times \epsilon_{\text{geom}}(\gamma/\text{Bq}) \times \epsilon_{\text{det}}(\text{cps}/\gamma)}$$

Where: A is the activity in Bq

M the measurement of the peak net area in counts per second (cps)

ϵ_{geom} the geometrical efficiency in gamma rays per Bq

ϵ_{det} the detector efficiency in cps per gamma ray

I is the probability of emission of a gamma ray per disintegration (in %)

Different codes can be used as gamma ray attenuation calculation. The use of the code is discussed below.

Which Model and Calculation to be Used?

A very precise model is often not needed. The model must only take into account the objects and layers between the assumed sources and the detector. Often the main uncertainties come from not knowing the thickness of the layers between the source and the detector. In that situation, a very precise code is not necessary.

Nevertheless, a more precise code can be useful when detailed information of the scene is available, when the geometry is complex, or when there is a need to reuse the geometry model for other applications. This case often occurs for hot cells modeling. Where high activities are concerned, the personnel issues at the facility are quite important and the time for modeling is significant.

ISOCS Use for Easy Modeling

CANBERRA ISOCS gamma code attenuation is the best compromise for a simple scene. The user interface uses templates which cover the most common geometries. With this approach, simple geometries can be modelled by technicians in less than 15 minutes. It allows the model to be done in the field during the measurement.

MERCURAD-PASCALYS Advantage

We have seen that MERCURAD is a complete 3D code for dose rate evaluation from any kind of gamma spectrum and activities. It can also be used to calculate activities from a measurement spectrum. This way to use MERCURAD is called PASCALYS.

The main advantage of PASCALYS compared to ISOCS is its modeling capabilities. Another advantage concerns the detector efficiency. As PASCALYS considers the detector as a point, any kind of detector can be used easily with this modeling approach.

The third advantage concerns the possibility of reusing the modeling scene. In a hot cell complete study, the geometry model can be used for other applications as health physics studies or dismantling scenarios.

With the MERCURAD-PASCALYS tool, a complex geometry can be generated and stored in a database. A complex geometry can be used by PASCALYS to determine activities from one field measurement, and then reused with MERCURAD to determine the activities dose rate. Objects can be easily removed from the scene (simulating dismantling activities) and dose rates recalculated.

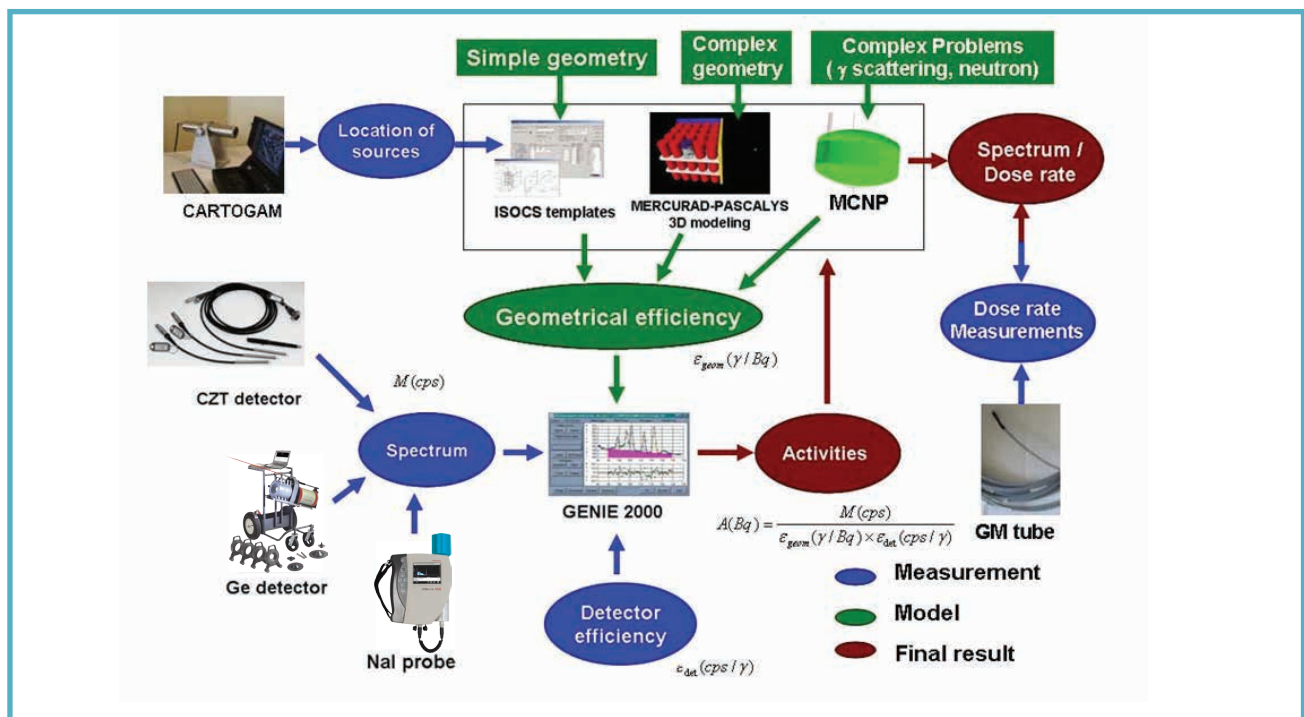


Figure 7
Multi detector in complex geometry modeling.

General Synthesis

During repairing and dismantling activities, multiple types of detectors can be used. As the source activities determination is very complex, different approaches may be selected according to the specifics of the site environment.

Regardless of the approach, the CANBERRA model used in the activity determination can be reused when dose rates have to be determined. It provides a consistent tool for engineering studies and dismantling scenarios.

PROJECT EXAMPLES

Calibration and Quality Assurance

Previously described tools and methodologies have been deployed to characterized different hot cells in the following types of facilities in the UP2 reprocessing plant at La Hague:

- HAO: High Activity Oxide facility where fuels are previously sheared and dissolved
- HADE: High Activity facility where Decanting, fission product and actinides Extraction are performed
- HAPF: High Activity facility where Products issued from Fission are stored

Measurement instruments were previously calibrated at a certified irradiator facility. Technical notes, procedure, and storage of scene modeling insure a complete traceability of the results.

Activity Determination in High Activity Hot Cells

The following methodology is performed by:

- Using laboratory sampling analysis to determine gamma and beta emitters and ratios
- Using equipment geometrical data as model and associated assumptions concerning liquid or sludge volumes
- Confirmation of sample analysis by dose rate measurements via very thin GM tubes and CZT gamma spectrometry measurement
- Model via MERCURAD code and MCNP to confirm MERCURAD results when gamma scattering effects occur
- Determination of transfer function at each measured point ($\text{Gy}\cdot\text{h}^{-1}/\text{Bq}$)
- Quadratic minimization of differences between dose rate measured values and model results

For example, the modeling of a very complex cell in the HAO facility was performed (see Figure 8). After fitting the 44 dose rate measuring points to MERCURAD dose rate results (from few mGy/h up to 8 Gy/h), the total beta activity was estimated at around 45 TBq.

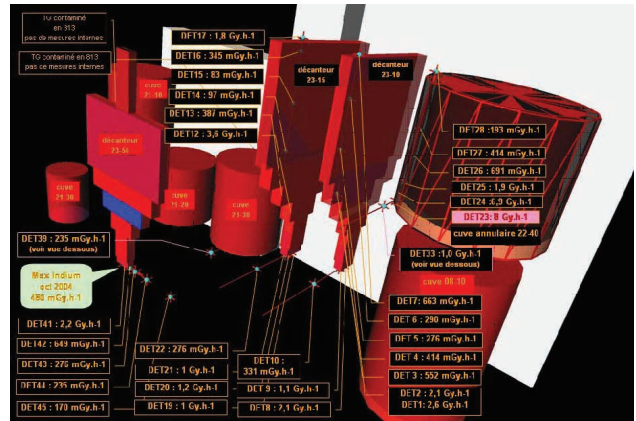


Figure 8 Modeling of one complex HAO cell.

A second example concerns the activity evaluation of tanks containing fission products.

The only probe to be introduced in this cell was the very thin CANBERRA Geiger Mueller detector (mounted inside an $\varnothing < 8$ mm thermowell). These GM tubes were previously calibrated in an irradiator to establish their response up to 200 Gy/h.

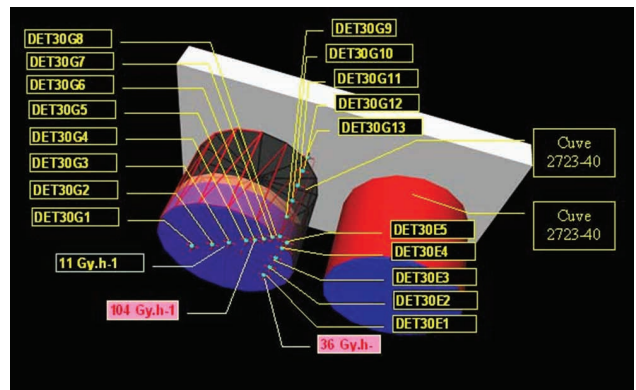


Figure 9 GM dose rate measurements on two tanks of fission products.

MERCURAD modeling was performed to determine the total beta activity, established around 2300 TBq and an uncertainty about 50%.

Measurement in Uranium Middle Activity Facility (MAU)

In the Middle Uranium Activity facility (called MAU), it is important to determine when the different tanks and equipment are considered to be sufficiently rinsed.

The aim is to make the equipment compatible with the very low activity wastes specification (called TFA). For Uranium, the TFA limit is about 100 Bq/g of final waste. Consequently, it is important to determine the classification of the equipment according to three different categories:

1. TFA or very low level waste
2. Not clearly TFA waste: equipment to be investigated
3. Clearly not TFA: equipment to be rinsed

Equipment may be differentiated according geometry and weight:

- Light (<500 kg)
- Intermediate (from 500 kg to 1 Ton)
- Heavy (>1 Ton)

By modeling the equipment MERCURAD inside the facility, it is possible to achieve different types of spectra, for example:

- Almost Uranium spectrum
- Almost ^{137}Cs spectrum

So, from the spectra, it is then possible to categorize the waste:

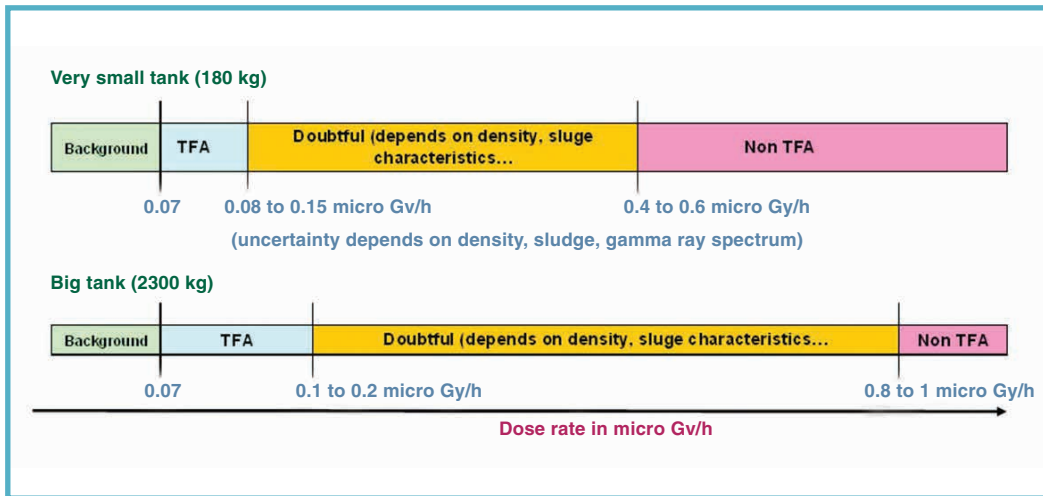


Figure 10
Differentiation between TFA, undetermined and non TFA waste.

For light equipment, it's very difficult to distinguish TFA and non TFA equipment as the limit around 80 nGy/h which is nearly the background. For large tank the limit value of 200 nGy/h is easier to measure.

With very easy hand-held gamma spectrometry measurement coupled with MERCURAD modeling, it becomes possible to successfully categorize the equipment.

CONCLUSION AND PERSPECTIVES

Different measurement and modeling approaches can be applied to address the unique problems facing each nuclear facility. Proper use of tools can help the investigation team and increase the knowledge of the radioactive contents of the facility. A complete set of solutions for radioactivity location and determination is available from CANBERRA.

Nuclear measurements can provide valuable information at several stages of a D&D project. Initially, nuclear measurements can form part of the preliminary assessment of the state of the installation. Once D&D activities are underway, nuclear measurement can help to provide better follow up of the operations. The benefits are numerous at each stage.

During the planning stages of a D&D project, evaluation of nuclear measurements can help:

- Improve operational efficiency: By defining and analyzing possible D&D scenarios before work begins, the most efficient and cost-effective scenario can be identified
- Improve operational safety: Insight provided by nuclear measurements can be used to make assumptions closer to the reality, thus minimizing risk and improving overall safety of the operation
- Shape contractual scope: a better knowledge of installation simplifies the writing of specification, ensuring that the scope will be clearly understood by all parties. With a clearer certainty of the level of effort required for the job, contingencies can be reduced, resulting in an overall cost reduction for the project

Once D&D activities begin, nuclear measurements can help to:

- Optimize cleaning phase. Cleaning can be done only when it is necessary and can be stopped at a predefine threshold
- Improve the waste stream and the waste categorization (activity, mass and volume)

This innovative use of available tools encourages sustainable development goals in a number of ways:

- Environmental aspects: reduction of the toxicity of the waste
- Social aspects: optimization of individual radiation exposure by detailed preliminary measurements, facilitating use of ALARA methodology

The described methodology helps to prepare and execute post-operational clean out and dismantling activities. Selection of the appropriate measurement tools can offer productivity gains and improve the final result. Ultimately, the methodology helps to provide a good level of decontamination and to optimize the final cost of dismantling.

References

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